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## Thin-Film Temperature Sensor

A thin-film capacitor sensor has been developed for measuring the rapid temperature changes in fluid streams. The sensor withstands contacts with various corrosive fluids, high fluid-flow rates, and the turbulences caused by rapid changes in flow rates.

The heart of the sensor is a temperature-dependent thin-film capacitor. Its temperature coefficient  $\alpha$  is defined by

$$\alpha = \frac{1}{C} \frac{dC}{dT} \quad (1)$$

where  $C$  is the capacitance and  $T$  is the temperature in degrees Kelvin. Thin dielectric films are generally known to have a large  $\alpha$ .

The capacitor is part of a resonant bridge circuit (Figure 1), which produces an ac voltage that is proportional to temperature. The output voltage  $V$  for a given temperature change  $\Delta T$  is described by

$$V = V_0 \alpha Q \Delta T \quad (2)$$

where  $V_0$  is the initial amplitude of the harmonic voltage applied across the capacitive element. In Figure 1, the capacitive element is represented in the dashed box by its parallel equivalent capacitance  $C$  and resistance  $R$ .

If low-loss coils  $L$  are used, the circuit quality factor  $Q$  is determined by the capacitive elements, namely

$$Q = \omega RC \quad (3)$$

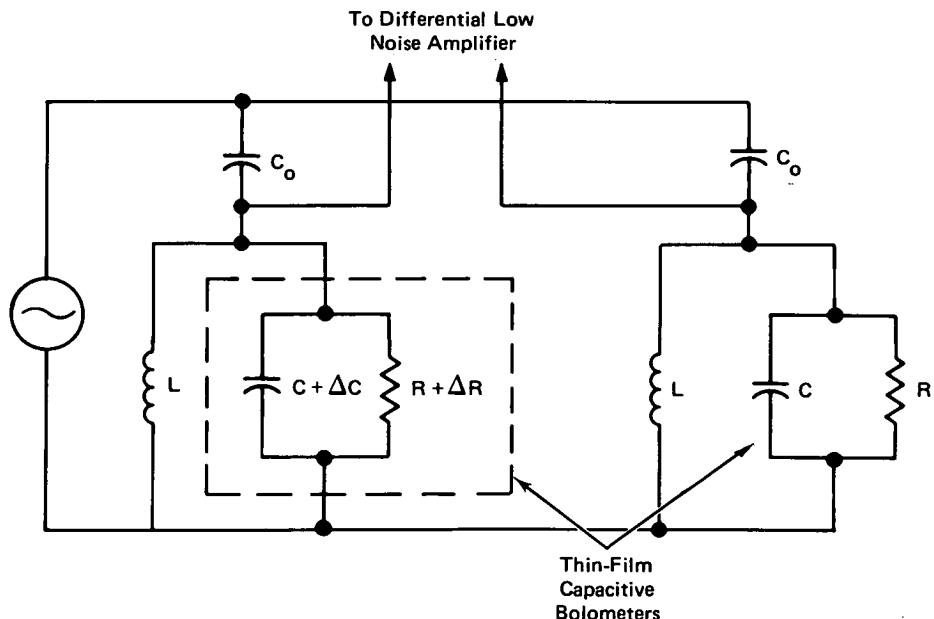


Figure 1. Resonant Bridge Circuit

(continued overleaf)

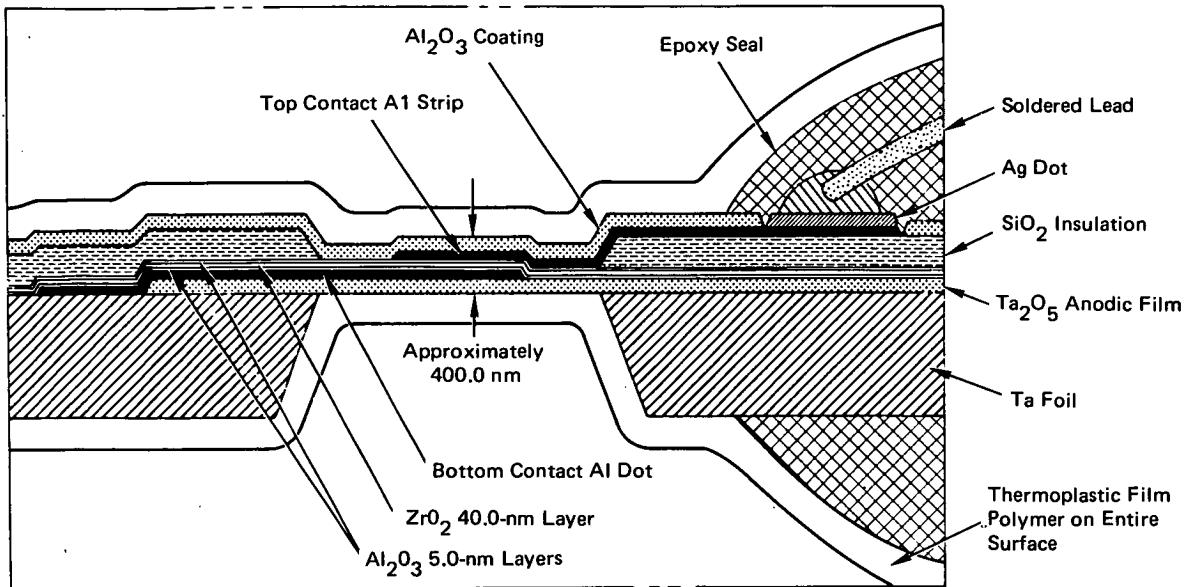


Figure 2. Temperature Sensor Structure

In this case,  $Q$  remains nearly constant for a wide range of frequencies  $\omega$ , because  $R$  is inversely proportional to  $\omega$ . The important parameters, therefore, that determine the temperature sensitivity of the sensor are  $\alpha$  and  $Q$ , as indicated in equation 2. The resonant bridge circuit produces an output voltage larger by the factor  $Q$  than the voltage from a simple capacitance bridge without coils.

The sensor consists of a tantalum foil supporting a thin-film capacitive element, as shown in Figure 2. The foil is 99.8-percent-pure tantalum approximately 0.025 mm (0.001 in.) thick. The capacitive element is formed by the vapor deposition of successive layers of aluminum, aluminum oxide ( $Al_2O_3$ ), zirconium oxide ( $ZrO_2$ ), silicon dioxide ( $SiO_2$ ), and aluminum. The aluminum strips form the capacitor electrodes, and the zirconium oxide with the aluminum oxide layers form the dielectric. In addition, a circular window approximately 0.38 mm (0.015 in.) in diameter is etched through the tantalum foil to the anodic film ( $Ta_2O_5$ ). The entire sensor is coated with a thermoplastic polymer, which provides chemical protection and electrical insulation.

#### Note:

Requests for further information may be directed to:  
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#### Patent status:

This invention has been patented by NASA (U.S. Patent No. 3,676,754). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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